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Movement of an Ice-Cored Rock Glacier, Tungsten, N.W.T., Canada, 1963-1980

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INTRODUCTION

In August 1963 Dr. H. Gabrielse, of the Geological Survey of Canada, established five lines of marked boulders on what is now believed to be a large ice-cored rock glacier near Tungsten, Northwest Territories. The boulders were aligned with survey targets located on the rock walls of the valley in which the rock glacier is located. The distances from the snout of the rock glacier to eight forest trees along its perimeter were measured and blazed into the trees. In July 1980, we visited the rock glacier and resurveyed the marked boulders and the rock glacier's snout in order to establish the rate and nature of movement of the rock glacier over the past 17 years.

SETTING AND DESCRIPTION OF THE ROCK GLACIER

The Tungsten rock glacier is situated 13 km southeast of the town of Tungsten, N.W.T. on the south side of the Flat River valley (Fig. 1). The rock glacier descends from about 1980 m to 1070 m elevation over about 2.7 km from a northeast-facing cirque. The bedrock and derived rubble which forms the surface of the rock glacier consists of dark grey argillites and argillaceous carbonates of Cambrian age (Roots *et al.*, 1966). The rock glacier can be subdivided into five distinct segments based upon surface morphology (Fig. 1, A-F).

1) The segment A-B includes the cirque and the uppermost several hundred metres of the valley below it. The cirque contains glacial ice, which has some collapse pits visible in it and which becomes debris-covered at the lower lip of the cirque. The lower part of the segment A-B is bracketed by lateral moraine-like ridges. The cirque glacier is formed by the coalescence of snow and ice cones formed beneath the 50-60 avalanche chutes which traverse the cirque wall.
2) Segment B-C is characterized by steep meandering longitudinal collapse depressions and transverse ridges superimposed upon a mound-like central ridge. This ridge is cut on both sides by marginal crevasse-like parallel features which, with the rock glacier's margin, form acute angles pointing downslope.
3) Segment C-D is marked by a sinuous narrow ridge bounded by collapse depressions. Some marginal crevasse features also are present over this segment.
4) Segment D-E is marked by transverse ridges and furrows which become progressively more pronounced further down the rock glacier.

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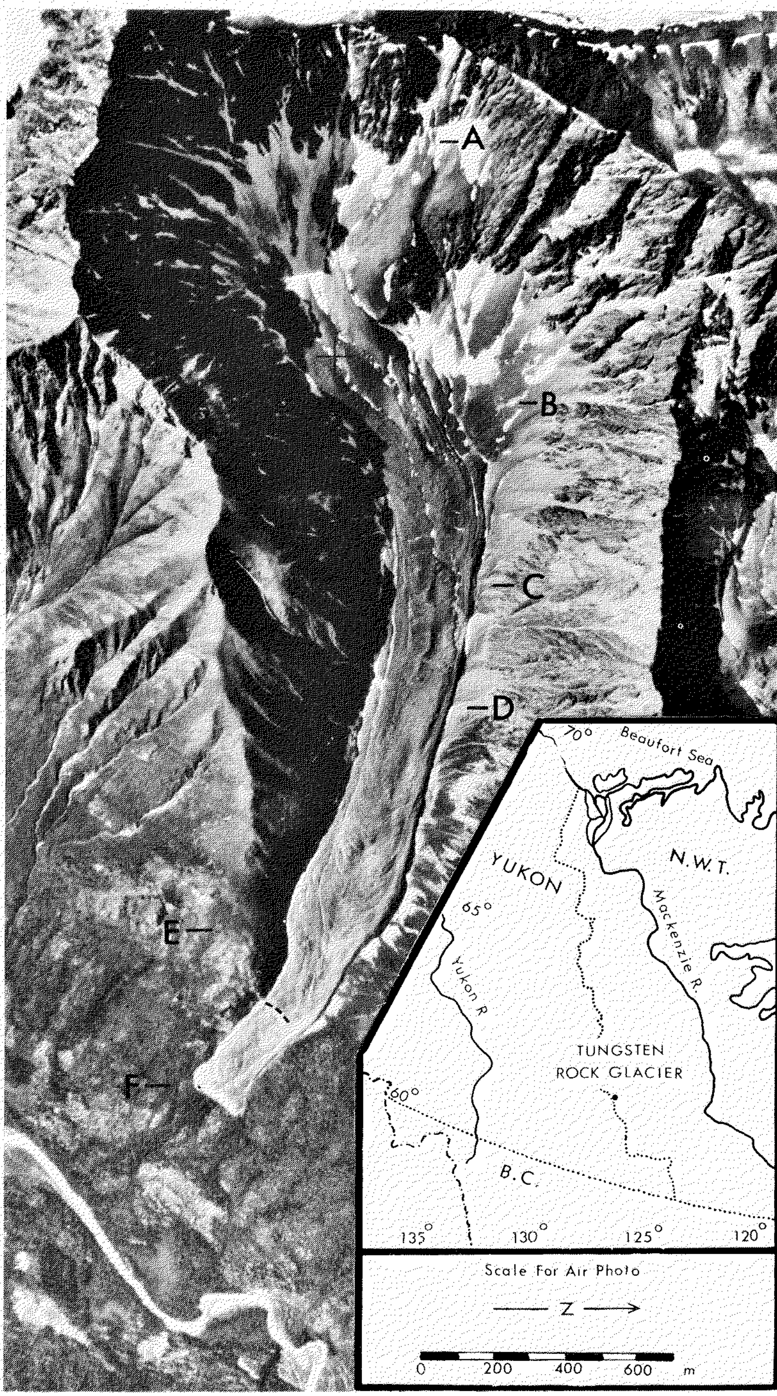

FIG. 1. **Location map and airphotograph of the Tungsten Rock Glacier taken in June 1950. Letters divide the feature into segments described in the text. The broken line designates the crown of a scarp (photo enlarged from National Air Photograph Library Photo 12637-107).**

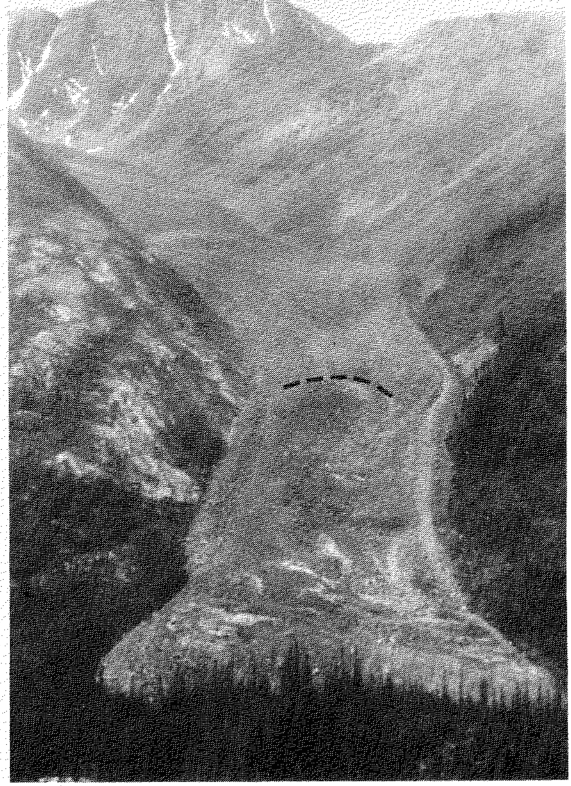

FIG. 2. Oblique airphotograph of the Tungsten rock glacier, taken in July 1980, showing the snout advancing into the forest. Note the well-developed lateral moraines. The broken line designates the crown of a scarp.

5) Segment E-F is dominated by longitudinal and transverse ridges.

Collapse pits are present in the centre of the rock glacier. The entire length of the rock glacier is marked by lateral moraine-like ridges (Fig. 1 and 2) except for the segment from the snout of about 100 m above it. Here it is not confined by valley walls and it is expanding laterally. The snout is 10-15 m in height and has a slope angle near the angle of repose ($-35°$). Detritus on its face is fresh and unvegetated. The exposed *in situ* detritus over the upper part of the snout consists of boulders in a matrix of silty, sandy gravel. Large boulders which have tumbled from face of the snout and lie on toppled green trees attest to the presently active movement of the snout. One large spring exits from the snout near tree 7.4 (Fig. 3). This position has been maintained since 1963. Its discharge is in the order of several hundred litres per minute. Evidence of two dry springs was also noted (Fig. 3).

The rock glacier's surface is almost entirely devoid of vascular plants with the notable exception of the lowest 100 m, where some scattered small willows and

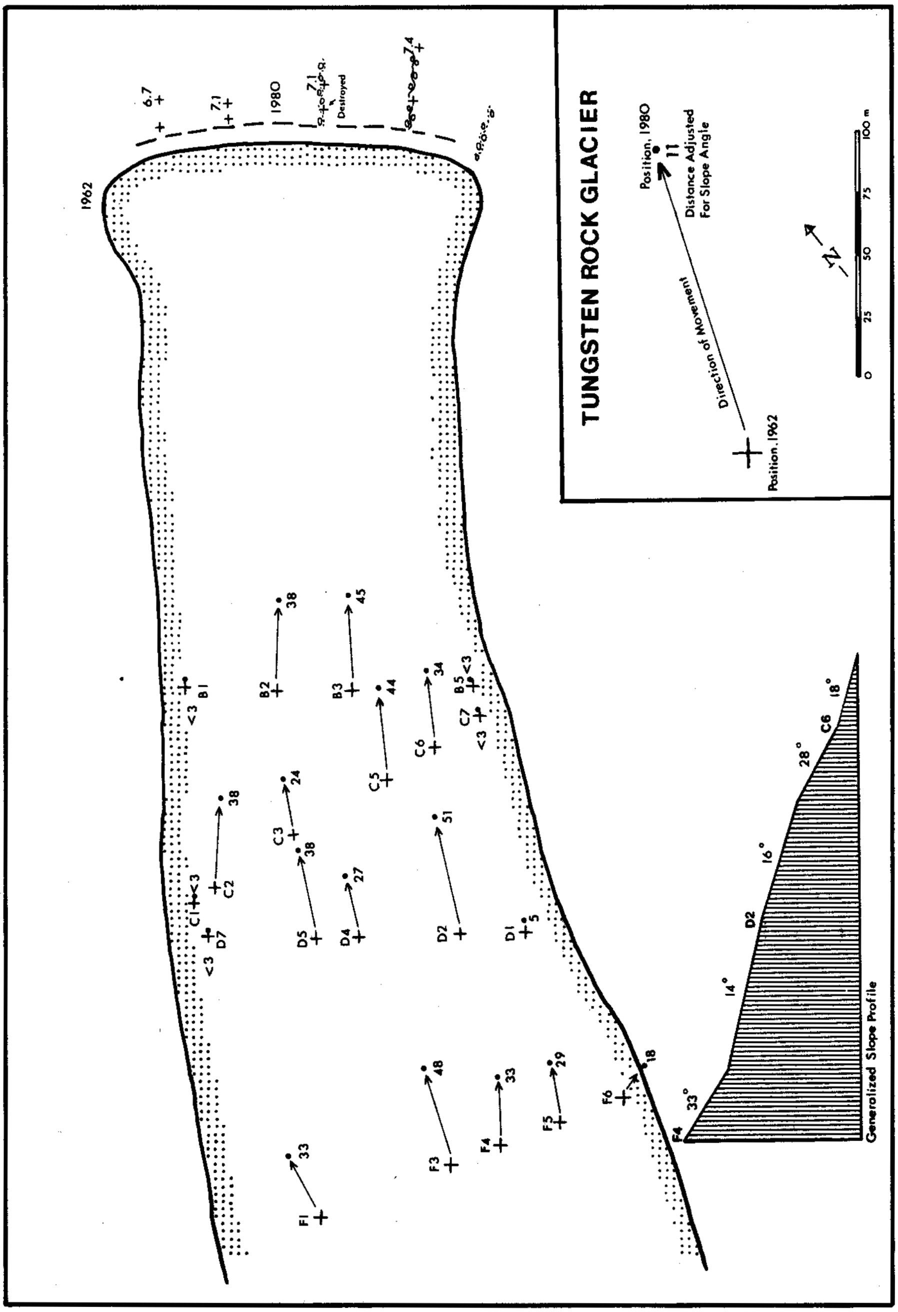

FIG. 3. Map showing the initial and present positions of marked boulders. The crosses below the snout indicate the positions of previously surveyed trees. The adjacent numbers indicate the distance of movement of the snout immediately adjacent to the trees. An active spring presently discharges from the rock glacier and the resulting stream flows past the tree marked by 7.4 m. Two presently inactive springs and stream beds are present on either side.

spruce are present. Crustose lichens are present on rocks throughout the surface of the rock glacier.

The presence of collapse pits and meandering longitudinal furrows were found by Vernon and Hughes (1966) to be diagnostic of a debris-covered glacier or, using the terminology of White (1976), an ice-cored rock glacier — the term we use in this paper. The presence of marginal crevasses also supports this contention. However, no ice was observed in the walls of the pits although water was heard flowing beneath the pits above the scarp crown designated by a broken line on Figures 1 and 2.

PREVIOUS WORK

Only one inspection of the marked boulders and the snout was made between 1963 and our survey. Hughes and Rapp (1965) found that the snout had moved up to 2.5 m and marked boulders up to 6.5 m. They concluded on the basis of collapse features that the rock glacier was ice-cored.

METHODOLOGY

Six lines of marked boulders were originally laid out between points E and F on Figure 1. Unfortunately, owing to inclement weather, we could locate the fixed survey markers for only the four lowest lines, from which we were able to find 22 of 25 marked boulders. We determined the new positions of the boulders by taking compass bearings from each rock to any two fixed survey stations using a Brunton compass. At the snout, we measured the distance from the toe of the rock glacier to previously blazed trees using a steel tape.

RESULTS

Both the original positions and the new positions of marked boulders are plotted on Figure 3. The numbers adjacent to the new positions of the rocks indicate the distance they moved along the surface. These figures were calculated by dividing the planimetric distance (indicated by the arrows) by the cosine of the mean slope angle of each segment of the rock glacier traversed by the boulders, as shown in the generalized slope profile on Figure 3. We estimate the error using the Brunton Compass for positioning at no more than 3 m. The present position of the snout is shown as the heavy broken line. The numbers below the snout indicate the amount of total movement since 1963.

DISCUSSION AND CONCLUSIONS

Our observations and data have enabled us to reach four conclusions with respect to the rate and nature of movement of this debris-covered rock glacier. First, the lateral moraine-like features appear to be almost stationary with respect to the rest of the rock glacier. Although the estimated maximum error of our boulder survey is about 3 m, it was almost possible to visually line up several of the boulders on the moraine with the fixed survey markers. Consequently, these boulders have probably moved less than one metre in seventeen years and the underlying features actually are lateral moraines.

Second, the rock glacier is glacier-like in its flow with respect to transverse surface velocity distribution. The flow velocity along each line of rocks generally increases toward the centre of the rock glacier, as is characteristic of a glacier.

Third, the surface velocity of the rock glacier over the monitored zone does not appear to be consistently proportional to surface slope. Rocks F-1 through F-5 on the whole traversed a linear distance approximately equal to or smaller than B, C, and D rocks in comparable positions, even though these latter rocks followed paths with significantly lower gradients (Fig. 3, inset). Although the limited data we collected do not permit us to offer an explanation for this phenomenon, several possible complicating factors which may contribute to this anomalous behavior can be identified. The paths traversed by boulders F-3 — F-5 are coincident with a scarp-like feature (indicated by the broken lines on Figures 1 and 2) that is itself coincident with a resistant bedrock spur which may, at least in part, control its position. The scarp may also represent a pull-away zone between a more mobile and rapidly moving segment below it and a less mobile and slower-moving segment above it. Possible explanations for differential mobility include variations in thickness, underlying topography, ice content or local gradation between ice-cored and ice-cemented rock glacier structure.

Fourth, the snout of the rock glacier is advancing more slowly than the marked rocks upslope. This differential appears to be at least partly taken up by lateral expansion of the snout which is not possible upslope due to constriction by the valley walls (Figs. 1 and 2). The remainder could be due to ablation of ice within the snout and/or increased basal friction caused by its advancement into forest.

ACKNOWLEDGEMENTS

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